High-Throughput Experimental Assays for High Cycle Fatigue

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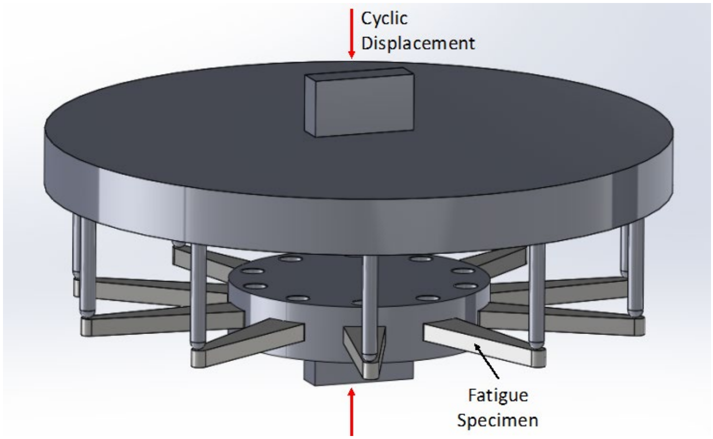
Objectives: Develop and demonstrate novel high-throughput fatigue test method for evaluating multiple samples on a single fatigue test system to address variability in life due to microstructure inhomogeneities.

Technical Approach: Unlike other high-throughput mechanical property measurements, a sufficiently large volume of the material needs to experience cyclic loading to increase the likelihood of encountering a critical inhomogeneity that promotes fatigue crack formation necessary to determine the lowest life under high cycle fatigue (HCF). Therefore, larger samples are preferable in a high-throughput fatigue method since more volume can be assessed in a single test. A novel approach of conducting assays with multiple bending fatigue specimens utilizing a standard servohydraulic test system is under development in the Mechanical Properties Characterization Facility. Under cyclic displacement control, assuming macroscopic elastic behavior and using tapered specimens, the cyclic stress (or equivalently strain) on the top surface of the fatigue specimen experiences uniform cyclic stress. Displacements are verified using digital image correlation (DIC) and finite element analysis. Possible crack detection methods include by load drop, electric potential drop, and DIC. With small modifications, the test apparatus can be placed inside a clam-shell furnace for evaluating HCF at high temperature.

Concept Illustration:



Impact: One of the major hurdles in using additive manufacturing (AM) to rapidly produce custom, complex, and topologically optimized structural components that will undergo cyclic loading in service is the uncertainty quantification (UQ) of the fatigue behavior. Fatigue crack formation is controlled by the local inhomogeneities in the microstructure. The relationship between these critical microstructure features and fatigue crack formation needs to be assessed. Because fatigue crack formation is driven by the extremums, a single test of a witness specimen in a build will not provide sufficient information to address the UQ. This new method enables the acceleration of alloy design by shortening the processing-structure-properties feedback cycle for fatigue critical components when sufficient historical data is not available.